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Abstract

Experience has been playing an important role in history of human and current social activities. Automating experience is also one of the most important parts for artificial intelligence. This paper will examine experience and experience based reasoning, experience management, experience engineering and their interrelationships. Then it will propose a unified architecture of experience engineering from a viewpoint of systems development methodologies. This architecture ties together philosophies, methodologies, techniques, tools and applications into a unified framework that includes both logical and intelligent embodiments of the aspects of experience engineering. The proposed approach will facilitate the development of experience management, experience engineering and knowledge based systems.

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The Engineering of Experience

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Abstract: Experience has been playing an important role in history of human and current social activities. Automating experience is also one of the most important parts for artificial intelligence. This paper will examine experience and experience based reasoning, experience management, experience engineering and their interrelationships. Then it will propose a unified architecture of experience engineering from a viewpoint of systems development methodologies. This architecture ties together philosophies, methodologies, techniques, tools and applications into a unified framework that includes both logical and intelligent embodiments of the aspects of experience engineering. The proposed approach will facilitate the development of experience management, experience engineering and knowledge based systems.

Keywords: Experience management, experience engineering, knowledge management, knowledge based systems.

1 Introduction

While the engineering of knowledge has become well-established in information systems (IS), business and management, artificial intelligence (AI), and information technology (IT) with books, conferences, commercial tools and journals on the topic [16][21], the engineering of experience has received a small amount of research attention, although research on a tool called the experience factory that has been used to store and retrieve experience in software development projects has led to some commercial product development [27].

While knowledge management (KM) has received considerable attention in the above mentioned areas [21], experience management has not drawn similar attention [5][18]. In particular, how to engineer experience management based on intelligent techniques and software engineering methodology is still a big issue.

Therefore, it is significant to examine the philosophy, methodology, reasoning, techniques and tools and their relationships for engineering experience. This paper will fill in this gap. To this end, the remainder of this paper is organised into the following sections: Section 2 examines experience and experience based reasoning (EBR). Section 3 looks at experience management taking into account KM. Section 4 examines experience engineering by proposing a unified architecture for engineering experience, which ties together concepts from all these separated fields into a unified framework that includes both logical and intelligent embodiments of the aspects of experience management and EBR. It is argued that such a unified architecture will facilitate the development of experience management, experience engineering and knowledge based systems. The final section concludes the paper with some concluding remarks.

2 Experience and Experience Based Reasoning

Knowledge, knowledge-based systems, knowledge management, and knowledge engineering as well as knowledge based reasoning have been an important part in computer science, IT, IS, business and commerce since the 1970's [13][9][16]. However, any investigation into knowledge and its management, reasoning and engineering without taking into account experience seems to be less meaningful [21], because experience is wealth for an individual or an organisation, just as knowledge is power and data is a basic resource for decision making and improving the competitiveness of an organization. Furthermore, possessing knowledge is only one necessary condition for a field expert [16]. Experience may be more important than knowledge for a field expert to deal with some tough problems such as clinical diagnosis. Accumulation of knowledge is the necessary condition of accumulating experience for a field expert.

Generally speaking, experience can be taken as previous knowledge or skill one obtained in everyday life [17] (p.13). In other words, experience is previous knowledge which consists of problems one has met and the successful solution to the problem. In CBR terminology, a piece of experience is denoted as a case [17]. All cases are stored in a case base. Therefore, a case base is essentially an experience base. A previous experience, which has been captured and learned in a way that it can be reused in the solving of future problems, is referred to as a past case [21]. Correspondingly, a new case or unsolved case is the description of a new problem to be solved and its possible solution. However, knowledge and experience are abstractions at two different levels. Experience is at a higher level, because experience can be considered as metaknowledge in some cases [17]. From a historical viewpoint, transforming the experience of a human being into knowledge has always been an important topic in science and technology. On the other hand, knowledge accumulation and distillation might lead to new experience.

From a logic viewpoint, there are eight basic inference rules for performing EBR and natural reasoning [19][20], which are summarized in Table 1, and cover all possible EBRs, and constitute the fundamentals for all EBR and natural reasoning paradigms [19][22]. The eight inference rules are listed in the first row, and their corresponding general forms are shown in the second row respectively. Because four of them, *modus ponens* (MP), *modus tollens* (MT), *abduction* and *modus ponens with trick* (MPT) [18] are well-known in AI and computer sciences [13][17], we do not go into them any more, and focus on reviewing the other four inference rules in some detail. First of all, we illustrate *modus tollens with trick* (MTT) with an example. We have the knowledge in the knowledge base (KB):

1. If Klaus is human, then Klaus is mortal
2. Klaus is immortal.

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What we wish is to prove "Klaus is human". In order to do so, let

- $P \rightarrow Q$: If Klaus is human, then Klaus is mortal
- P: Klaus is human
- Q: Klaus is mortal.

Therefore, we have P: Klaus is human, based on MTT, and the knowledge in the KB (note that $\neg Q$: Klaus is not mortal).

*Abduction with trick (*AT) can be considered as a "dual" form of abduction, which is also the summary of a kind of EBR [19]. Abduction can be used to explain that the symptoms of the patients result from specific diseases, while abduction with trick can be used to exclude some possibilities of the diseases of the patient [22].

Inverse modus ponens (IMP) is also a rule of inference in EBR [19]. Furthermore, EBR based on IMP is a kind of common sense reasoning, because there are many cases that follow IMP. For example, if John has enough money, then John will fly to China. Now John does not have sufficient money, then we can conclude that John will not fly to China.

The last inference rule for EBR is *inverse modus ponens with trick* (IMPT) [19]. The difference between IMPT and IMP is again "with trick", this is because the reasoning performer tries to use the trick of "make a feint to the east and attack in the west"; that is, he gets Q rather than $\neg Q$ in the *inverse modus ponens*.

Table 1: Experience-based reasoning: Eight inference rules.

MP	MT	abduction	MTT	AT	MPT	IMP	IMPT
$\dfrac{P \quad P \rightarrow Q}{\therefore Q}$	$\dfrac{\neg Q \quad P \rightarrow Q}{\therefore \neg P}$	$\dfrac{Q \quad P \rightarrow Q}{\therefore P}$	$\dfrac{\neg Q \quad P \rightarrow Q}{\therefore P}$	$\dfrac{Q \quad P \rightarrow Q}{\therefore \neg P}$	$\dfrac{P \quad P \rightarrow Q}{\therefore \neg Q}$	$\dfrac{\neg P \quad P \rightarrow Q}{\therefore \neg Q}$	$\dfrac{\neg P \quad P \rightarrow Q}{\therefore Q}$

It should be noted that the inference rules "with trick" such as MTT, AT, MT and IMPT are non-traditional inference rules. However, they are really abstractions of some EBR and natural reasoning, although few have tried to formalize or automate them. The "with trick" is only an explanation for such models. One can give other explanations for them. For example, one can use fraud or deception [19] or exception to explain them. Therefore we can obtain the corresponding five inference rules for reasoning with deception or reasoning with exception.

3 Experience Management

While knowledge management is currently an important discipline in information systems (IS), IM, and AI [6][9][16], experience management is one of the most challenging areas in IS, IM and AI research community [5][21]. In what follows, we will examine EM in some detail.

From an object-oriented viewpoint [15][21], a subclass Y inherits all of the attributes and methods associated with its superclass X; that is, all data structures and algorithms originally designed and implemented for X are immediately available for Y [14] (p 551). This is the inheritance or reuse of attributes and operations. As we know, experience can be considered as a special case of knowledge (see Section 2), methodologies, techniques and tools for KM can be directly reused for EM, because EM is a special kind of KM that is restricted to the management of experience. On the other hand, experience has some special features and requires special methods different from that of knowledge, just as a subclass Y of its superclass X usually possesses more special attributes and operations. Therefore, two issues are very important for EM:

- What features of experience management (EM) are different from that of KM?
- Which special process stages does EM require?

In what follows, we will try to resolve these two issues. First of all, we define that EM is a discipline that focuses on experience processing and corresponding management [16], as shown in Fig 1. The experience processing mainly consists of the following process stages [5] (pp 1-14):

- Discover experience
- Capture, gain and collect experience
- Model experience
- Store experience
- Evaluate experience
- Adapt experience
- Reuse experience
- Transform experience into knowledge
- Maintain experience.

where, management has permeate each of above-mentioned process stages [16], which is distinguished from other process model of either experience management [5] or knowledge management [6]. In these process stages, "maintain experience" includes update the available experience regularly, while invalid or outdated experience must be identified, removed or updated. Transform experience into knowledge is an important process stage for EM, which is the unique feature of EM different from those of KM. In the history of human beings, all invaluable experience is gradually transformed into knowledge, which then is spread widely in a form of books, journals and others means [16].

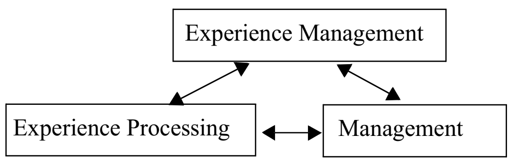

Fig. 1. KM as integration of knowledge processing and management

From an IT viewpoint, discovery of experience from a collection knowledge or social practice is still a significant issue for EM, like discovery of knowledge from a huge database [21].

It should be also noted that from the history of modern computing, any reasonable abstraction from data has facilitated the research and development of IT. For example, the abstraction from data to information led to the fast development of information modelling, processing, engineering and IM [17]. Based on this idea, we can see that the abstraction process from data to experience requires corresponding processing technology such as data processing, information processing, knowledge processing and experience processing which further involve data management, information management (IM), KM (including intelligent agents and ES) and EM respectively. That is, human-level experience processing also requires EM. Just as data management, IM, and KM have played an important role in IT, IS, and AI, EM will also play an important role in IS and e-commerce.

4 Experience Engineering: A Unified Architecture

In the previous sections we have examined experience, experience based reasoning and experience management. All of these are the important components for automating or engineering experience.

Experience engineering (EE) is a new research field, comparing with data engineering, information engineering, knowledge engineering [4] and the engineering of mind [2]. However, EE will be an important part of AI, because experience is an important component of our mind and intelligence [23].

EE is the establishment and use of sound engineering principles in order to obtain economically experience for an organisation [14][23]. EE is the application of systematic, disciplined, quantifiable approaches to the modelling, processing, simulation, management and development of experience in order to obtain economically experience for an individual or organisation, because engineering here is the analysis, design, construction, verification, modelling, management of technical (or social) entities [14]. Some approaches in design or maintenance like "return of experience methods" in CommonKADS (http://www.commonkads.uva.nl/) or modelling like the notion of reference model in CIMOSA (http://pera.net/Arc_cimosa.html) can be also considered as a part of EE.

EE is heavily affected by the research and development of EE philosophies, EE methodologies, EE models and techniques, EE tools and then EE applications and their interrelationships, from a viewpoint of systems development methodologies [3][23], which constitutes a unified architecture for EE, as shown in Fig. 2.

In this architecture, experience engineering (EE) depends on different EE philosophies. In other words, there are many different EE philosophies for engineering experience. For any $i \in \{1, 2, \ldots, I\}$, EE philosophy i corresponds to an important perspective to EE. For example, case-based reasoning (CBR) is a kind of experience-based reasoning [8]. The philosophy of CBR is "similar problems have similar solutions" [17].

EE methodologies are the realization of the EE philosophies. Generally speaking, there are many different methodologies corresponding to one EE philosophy, while for any $j \in \{1, 2, \ldots, J\}$, EE methodology j can also serve many different philosophies. For example, at least five different methodologies serve the CBR philosophy, that is, the cognitive methodology of CBR [10], the process-driven methodology of CBR [1], the intelligent methodology of CBR, the logical methodology of CBR, the hybrid methodology of CBR [8], while the logical methodology of CBR can serve not only the CBR philosophy but also the e-commerce philosophy [17].

EE models and techniques are the realization of the EE methodologies. There are many models or techniques corresponding to one EE philosophy. For example, in order to understand experience based reasoning (EBR), Sun and Finnie proposed logical model and fuzzy logic model of EBR, which is also a part of EE. Furthermore, for any $l \in \{1, 2, \ldots, L\}$, the EE model or technique l also serve some EE methodologies.

EE tools or toolsets are tools that help to transfer the EE models or techniques to EE systems or experience based systems (EBS) in order to solve a real world experience-related problem. many EE tools can correspond to an EE model or technique. For any $m \in \{1, 2, \ldots, M\}$, the EE tool m can serve developing an EBS based on one or more EE models or techniques. Experience factory [27] can be considered as EE tool. C++ and Java are also useful programming tools for developing EBSs.

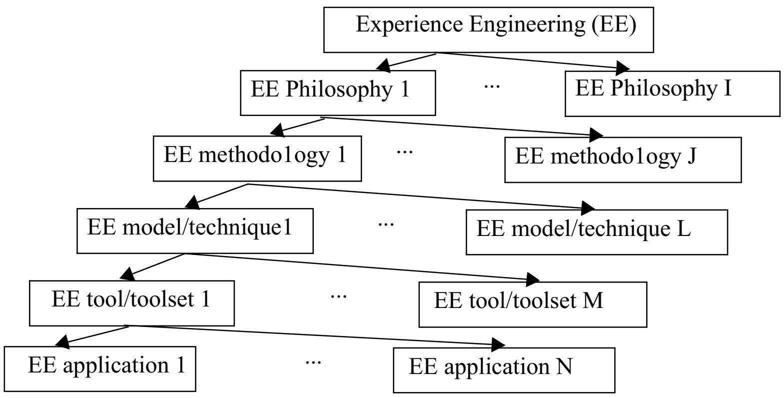

Fig. 2. A unified architecture of experience engineering

The EE applications can be considered as the implementation of either EE models or techniques or methodologies or philosophies based on EE tools or toolsets. Generally, for any $n \in \{1, 2, \ldots, N\}$, EE application n requires the usage of many EE tools or toolsets, while one EE tool can also serve the implementation of many EE applications.

Based on the above architecture, EE consists of a collection of EE philosophies (principles), methodologies, models, techniques, tools and applications that are correlated closely among themselves. The research and development of EE relies on the dynamic development of these philosophies, methodologies, models, techniques, tools and applications in the near future. More specifically, EE consists of $I \times J \times L \times M \times N$ attempts of research and development in the fields of EE philosophy, methodology, model/technique, tool/toolset, and application, in order to automate experience of human beings. Any attempt belonging to this set will be useful for the development of EE with applications.

It should be noted that this proposed architecture is hierarchical for brevity. In reality, the interrelationships or correlations among philosophies, methodologies, techniques, tools and applications are so complex that we can model them in many different ways. For example, we can use a *n*-complete graph to model them. We can also use a cyclic graph to model them, which will be discussed in another paper owing to the space limitation of the paper.

5 Concluding Remarks

This paper examined experience, experience based reasoning, experience management, experience engineering and their interrelationships based on a general architecture of experience engineering from a viewpoint of systems development methodologies.

Research and development of experience engineering (EE) will provide a new way of looking at data, knowledge, experience and their management for individuals or organisations. This will include experience structures, experience retrieval, experience similarity, experience processing and experience adaptation, and EBR. Successful solution of these problems could provide the basis for new advances in EM and EE. There is also significant potential for EE in opening up a new broad range of applications, not only in business and e-business but in a number of domains such as deception and fraud recognition [19].

In future work, we will develop a system prototype for multiagent experience based systems, which can be used for business negotiation and brokerage. We will examine EE using similarity-based reasoning and fuzzy reasoning. We will also examine interrelationships between EE and other research fields such as cognitive science and database.

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